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4.1 Impacts of climate change on Snake River salmon

A case study in
interconnections and complexity

Lisa Crozier and Rich Zabel

West Coast Protected Fish Species Program Review

Seattle, WA

May 4, 2015

Science to support management needs

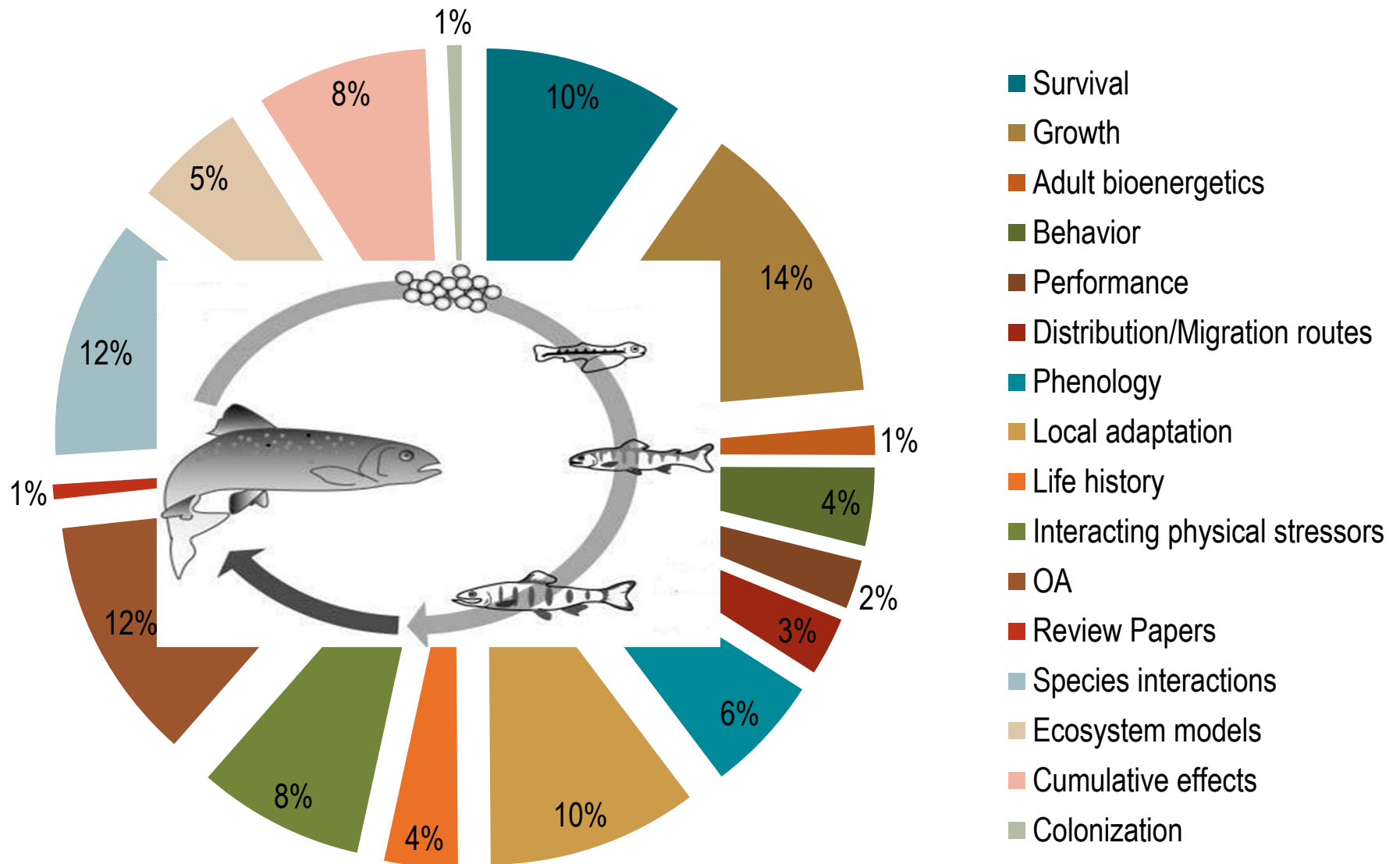
- Relative vulnerability to climate impacts
- Actions that will benefit populations
- Population-specific viability assessment
- Characterize uncertainty in climate change analyses

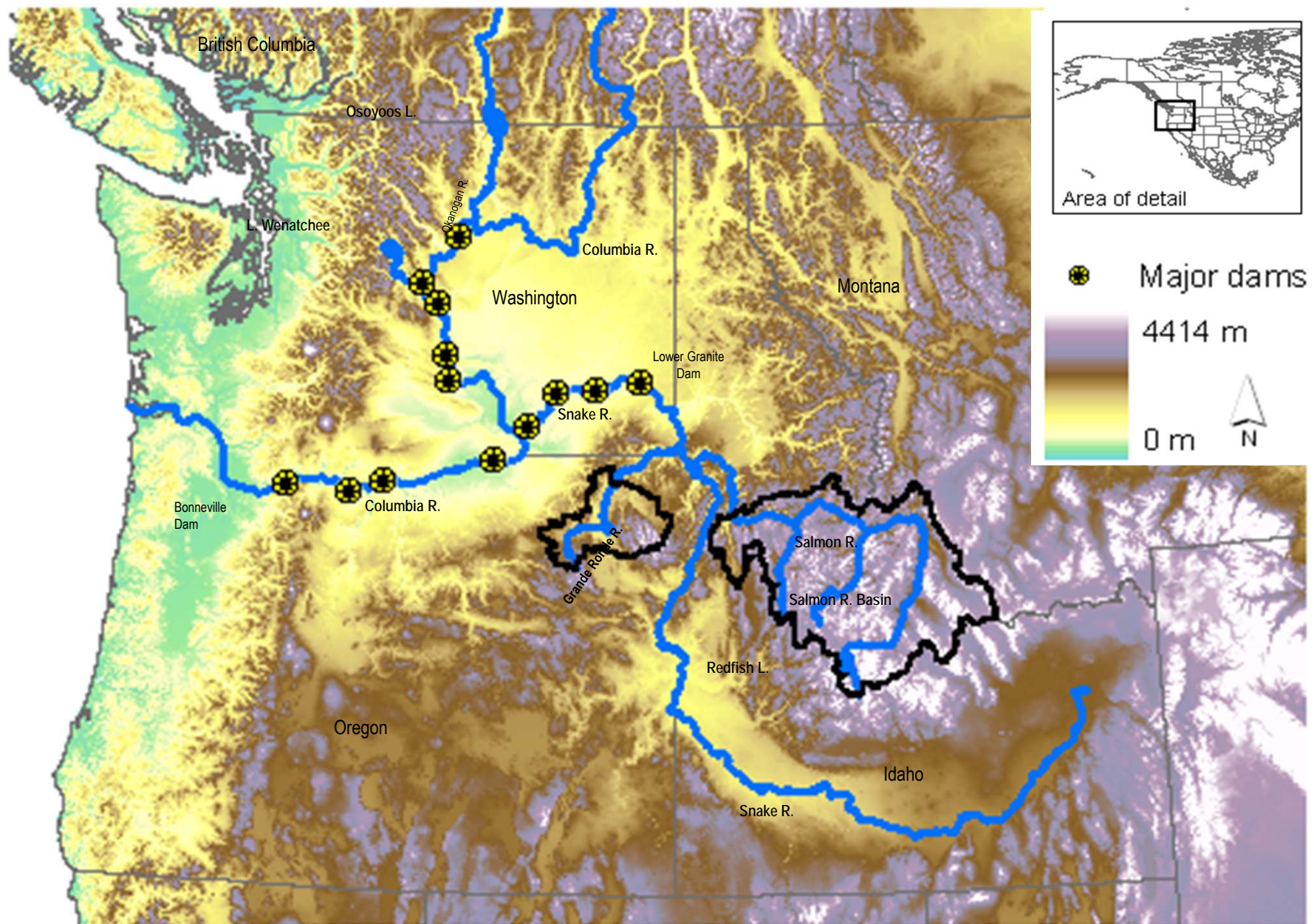
Case study of salmon in the Columbia River Basin

- Annual literature reviews
- Life-cycle models as conceptual and quantitative tools
- Build knowledge over time to incorporate a wider variety of direct and indirect effects quantitatively

1100 Papers on Climate Change & Impacts on Salmon 2010-2013

All life stages, ecological and evolutionary dynamics affected

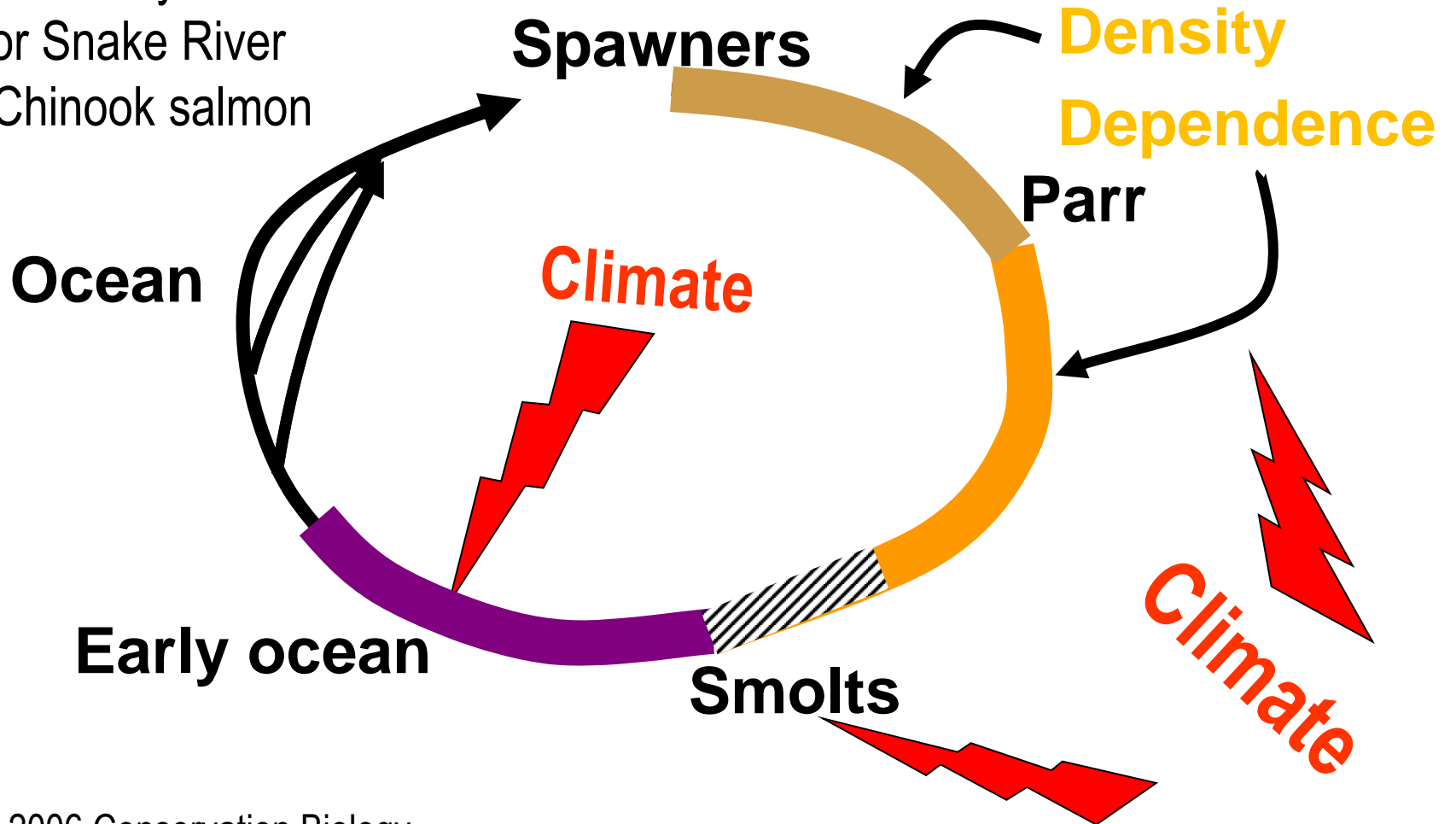




Snake River spring/summer Chinook salmon ESU

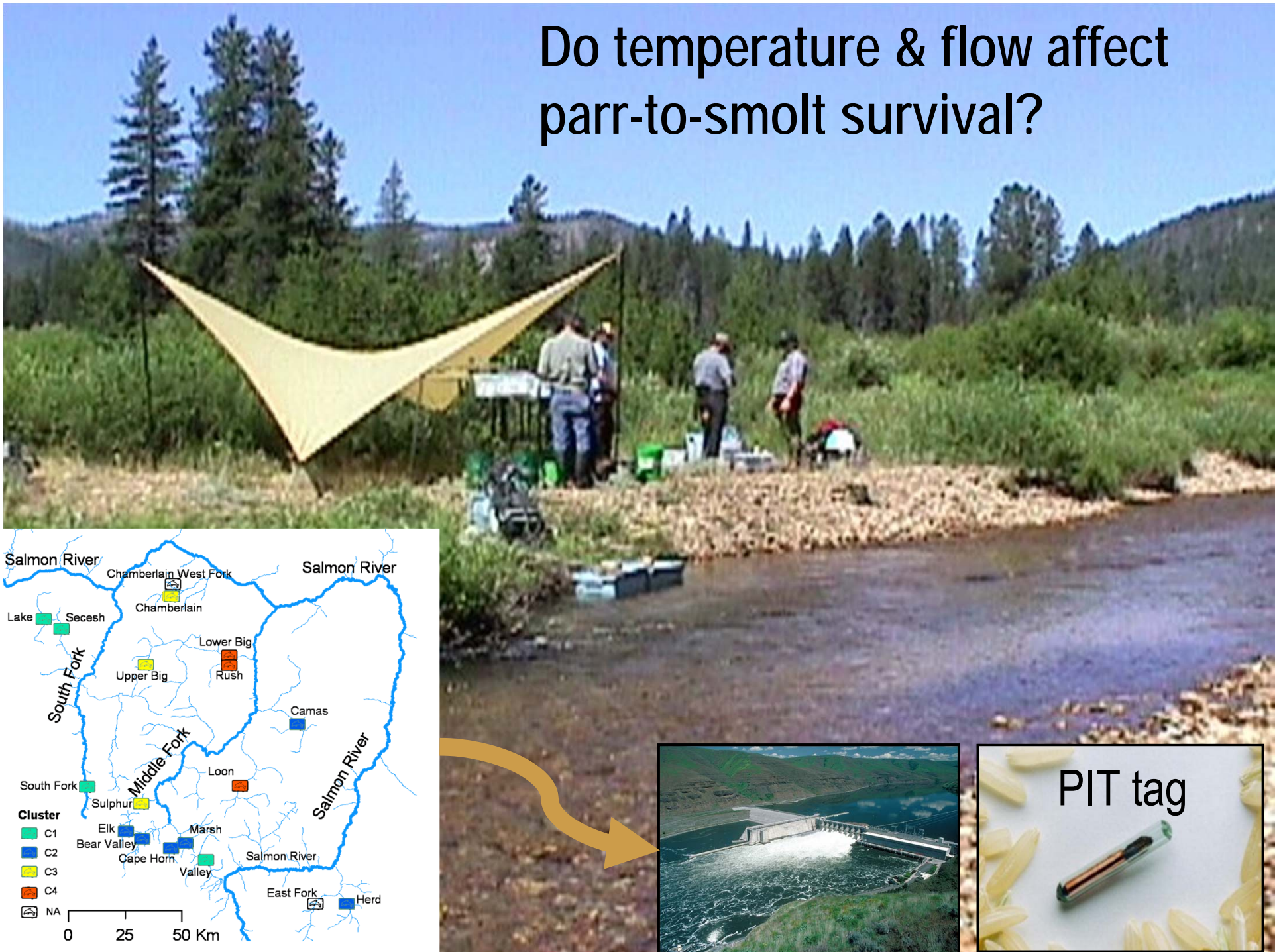
Population Viability Analysis

Stochastic life-cycle
model for Snake River
Spr/Su Chinook salmon



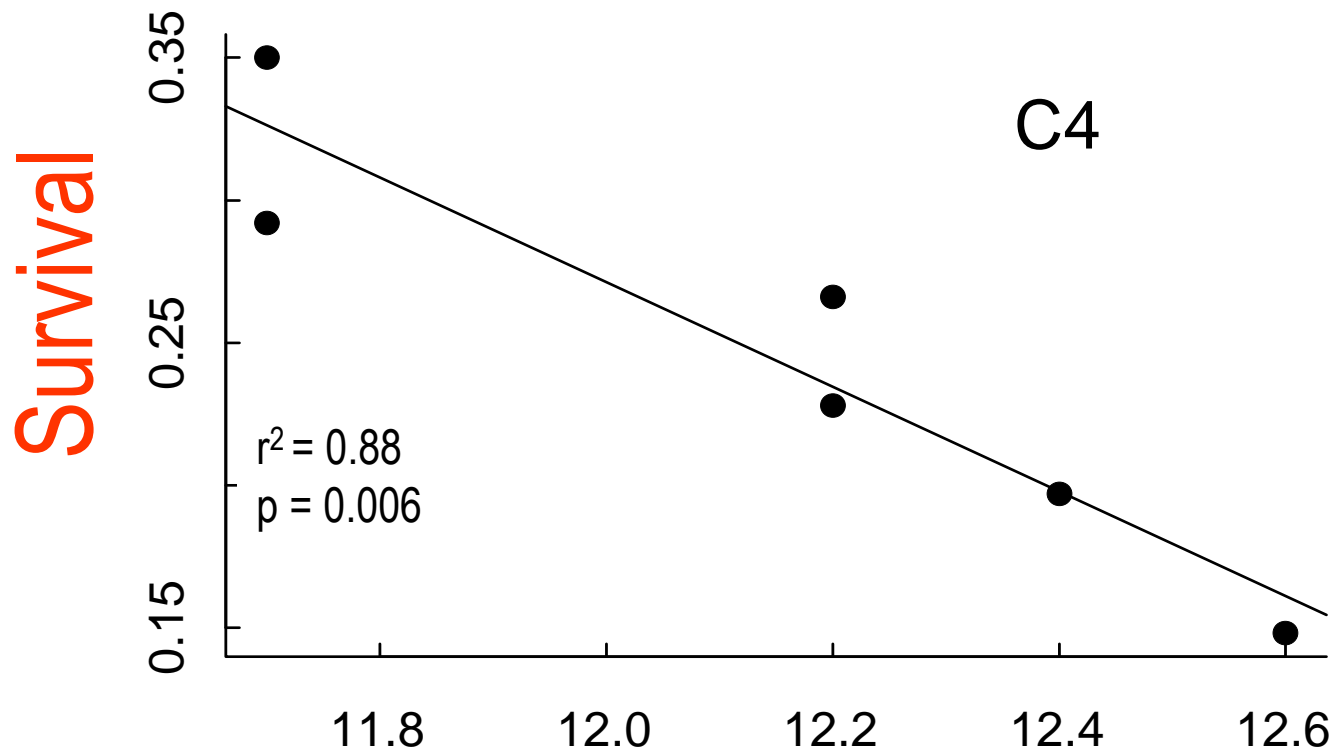
Zabel et al 2006 Conservation Biology
Crozier et al 2008 Global Change Biology
Crozier and Zabel 2013 Integrated Ecosystem Assessment

Do temperature & flow affect parr-to-smolt survival?



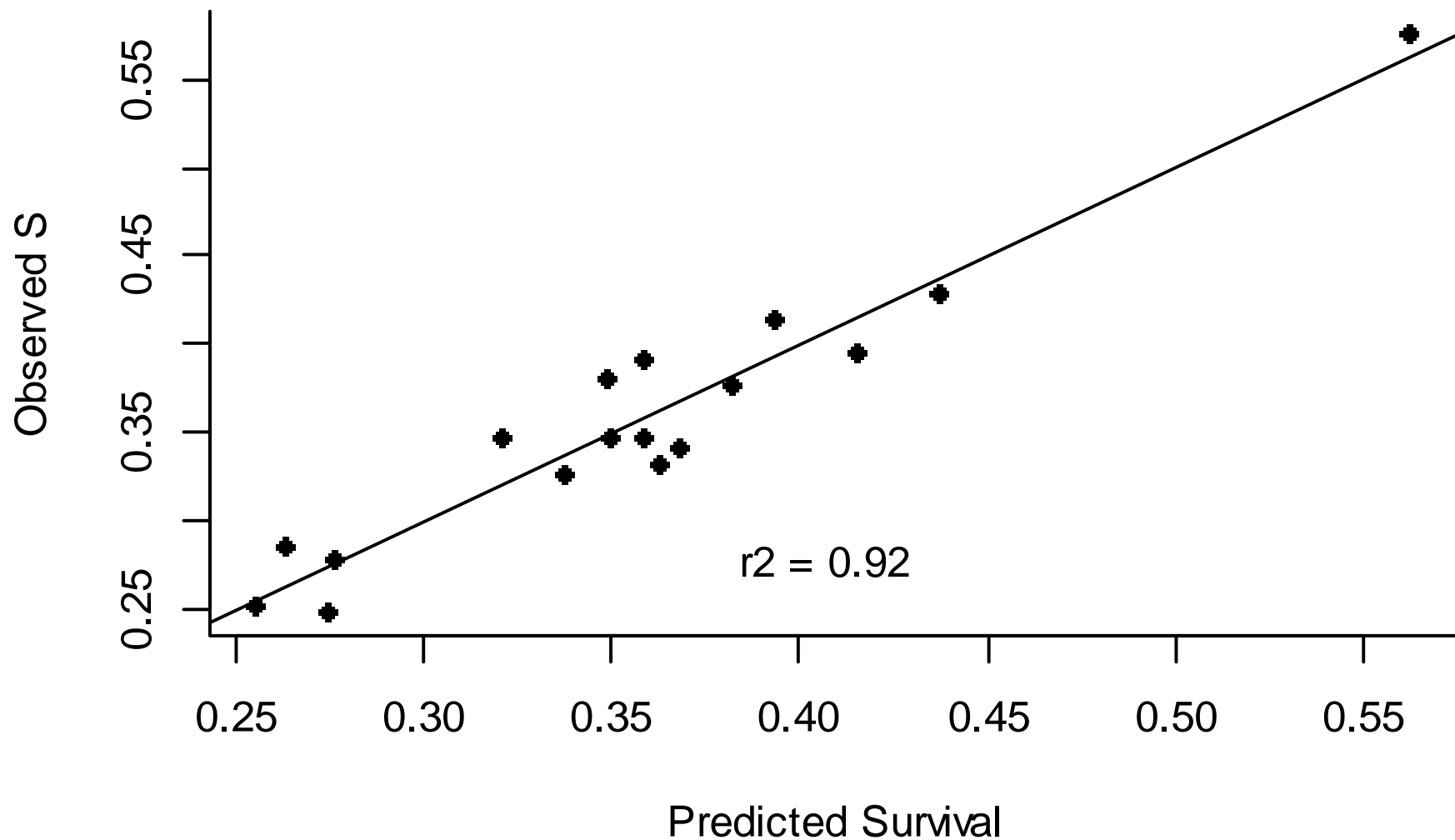
Population-specific sensitivity

Temperature-sensitive populations

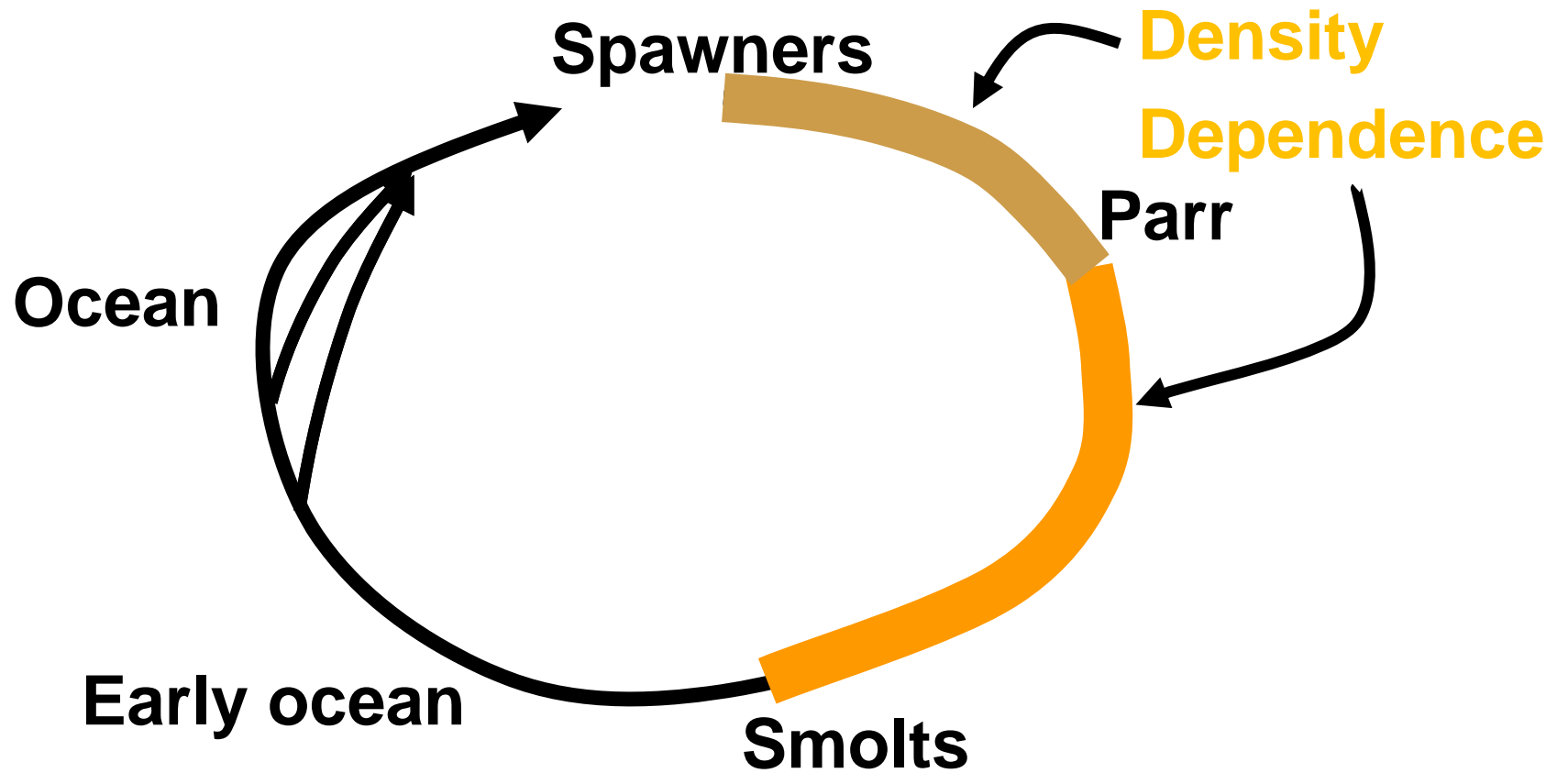


Summer stream temperature (°C)

Parr to smolt survival: Flow + fish condition (length)

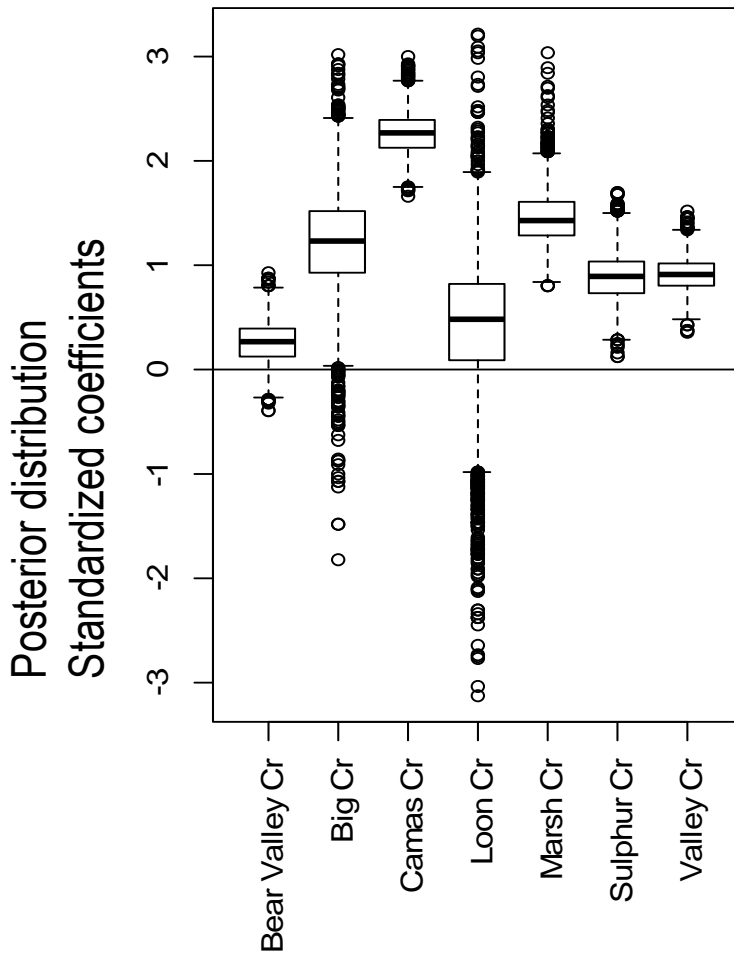


Life-cycle model

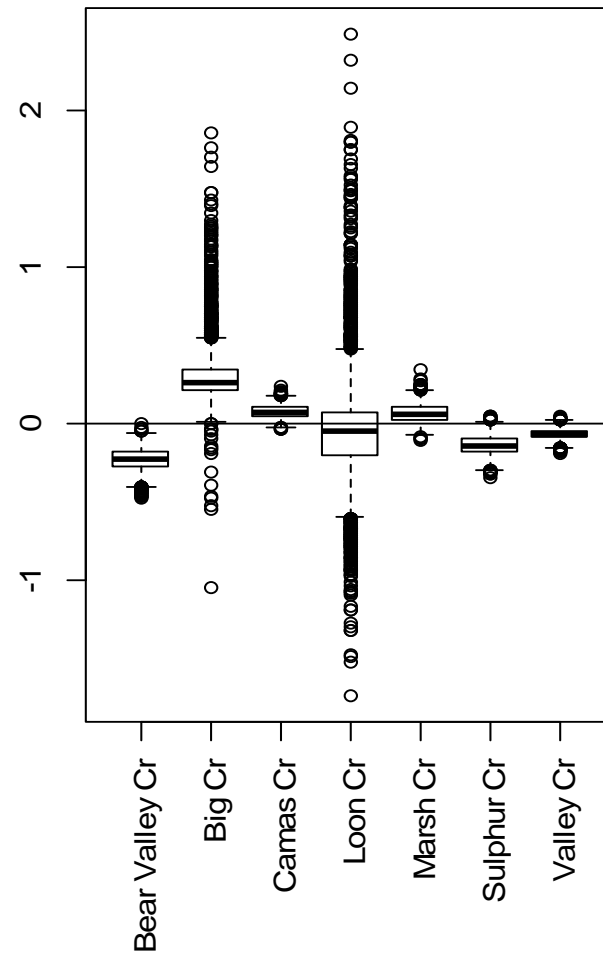


Uncertainty and variation in population response in carrying capacity term of Beverton-Holt relationship

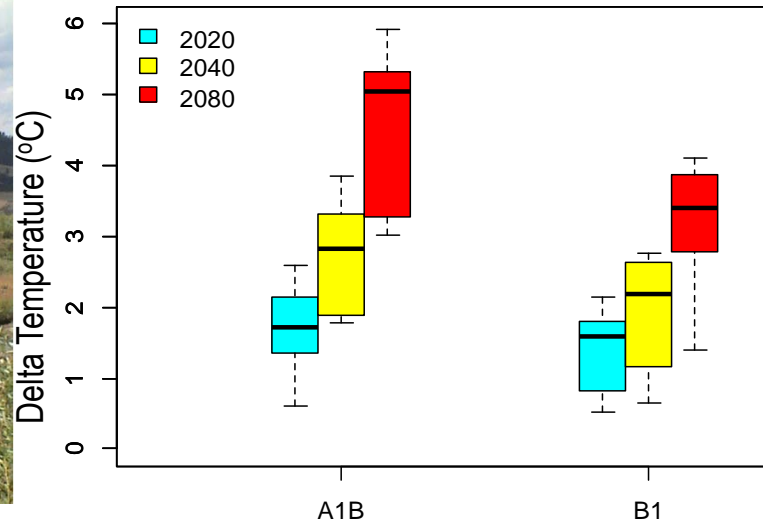
FLOW



TEMPERATURE

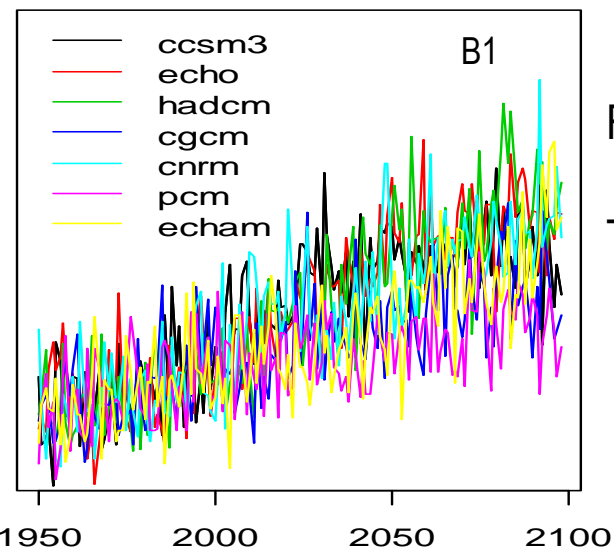
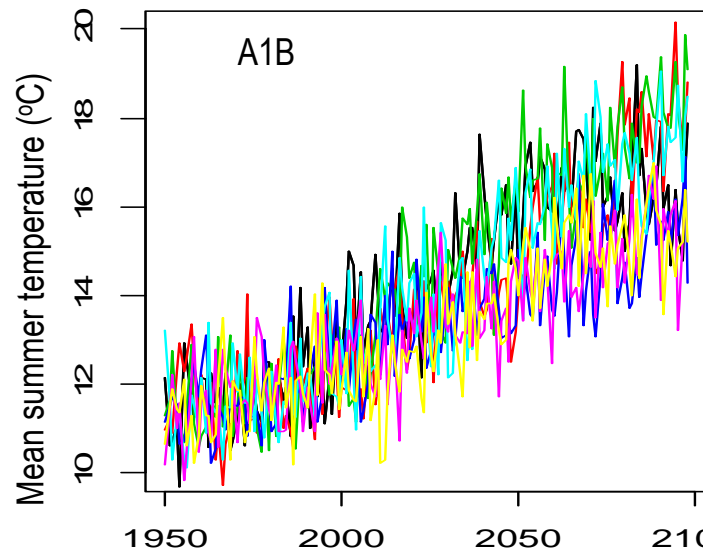


40 Headwater Climate scenarios



2 emissions : A1B & B1
10 GCMs
“hybrid-delta” method
VIC hydrological model

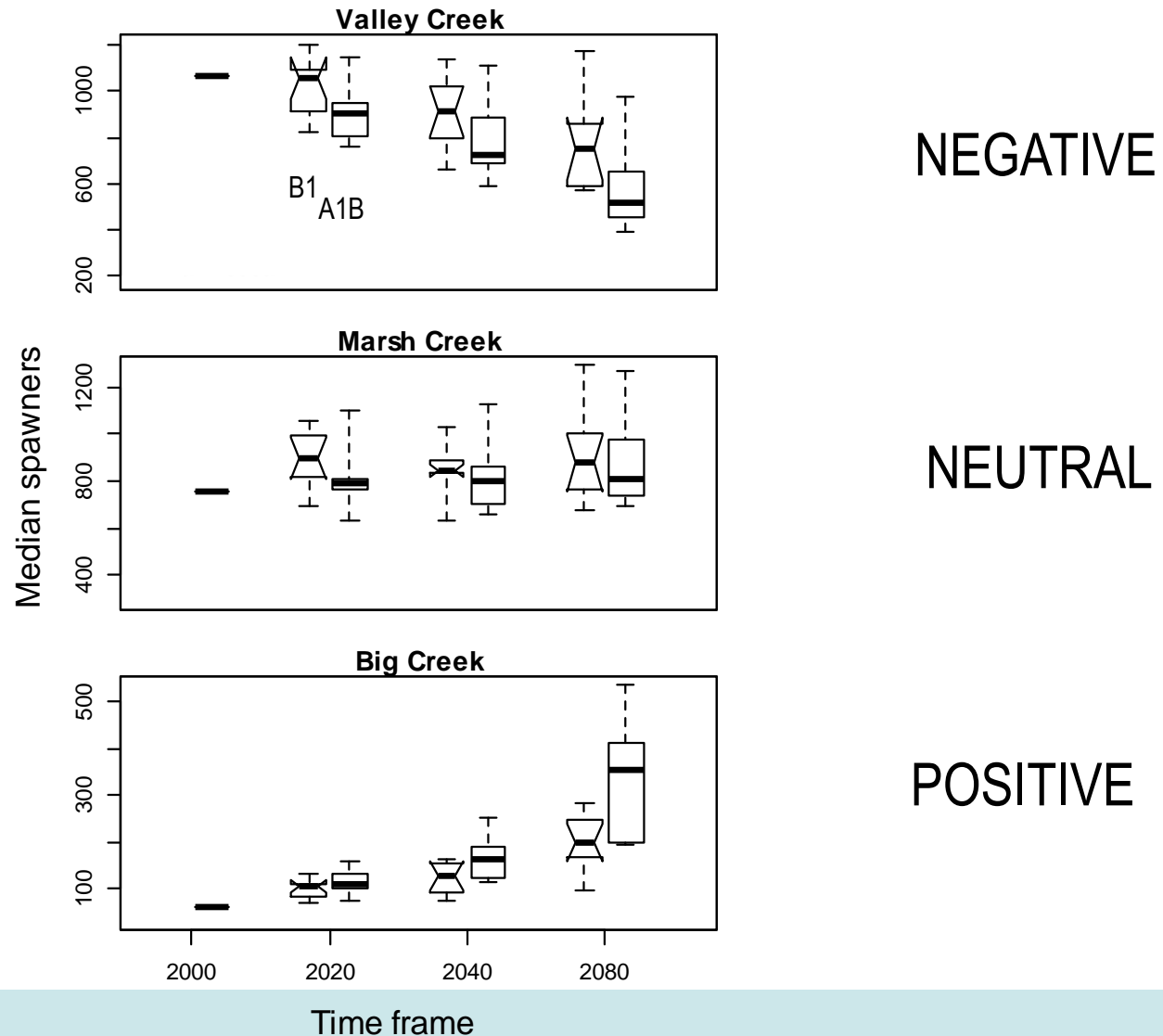
Downscaled by
Climate Impacts Group,
University of Washington



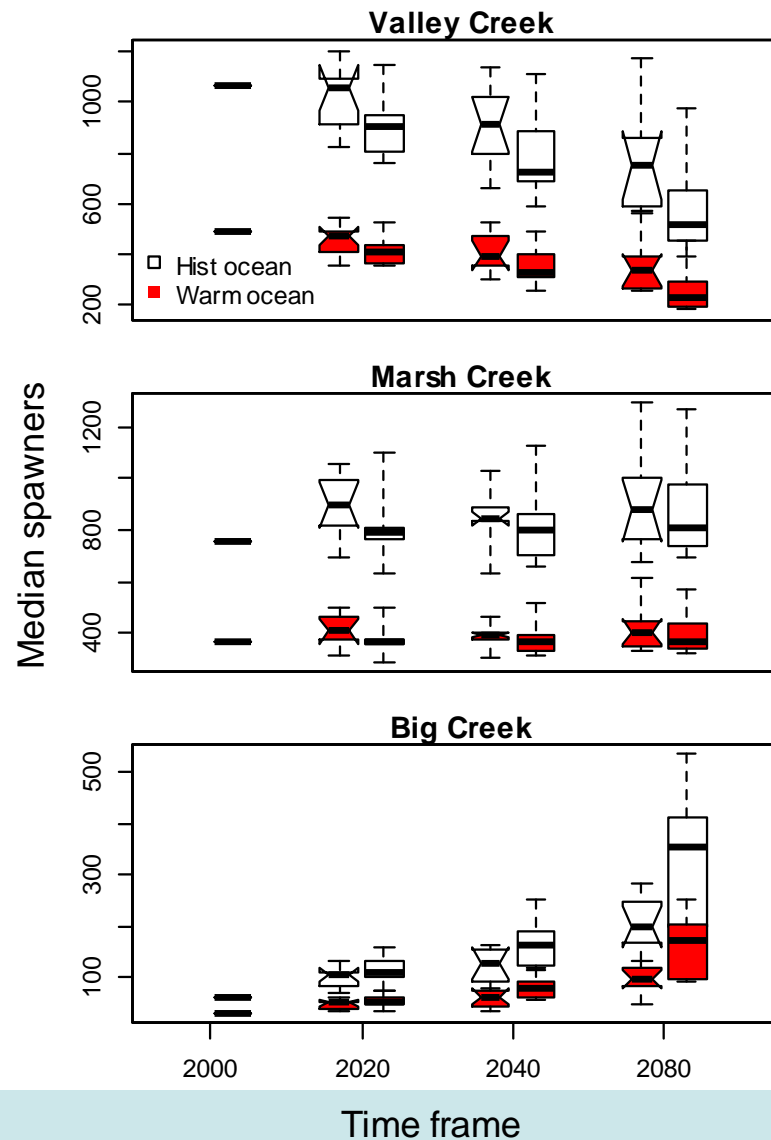
Fixed time periods
vs
Transient scenarios

RESULTS

The effects of FW climate change on spawner abundance



Poor ocean conditions dramatically lower abundance in all populations



Mainstem Columbia & Snake River survival

Historical

Wet / more warming -- A1B MIROC 3.2 Global Climate Model

Dry / less warming -- B1 ECHO_G 3.2 Global Climate Model

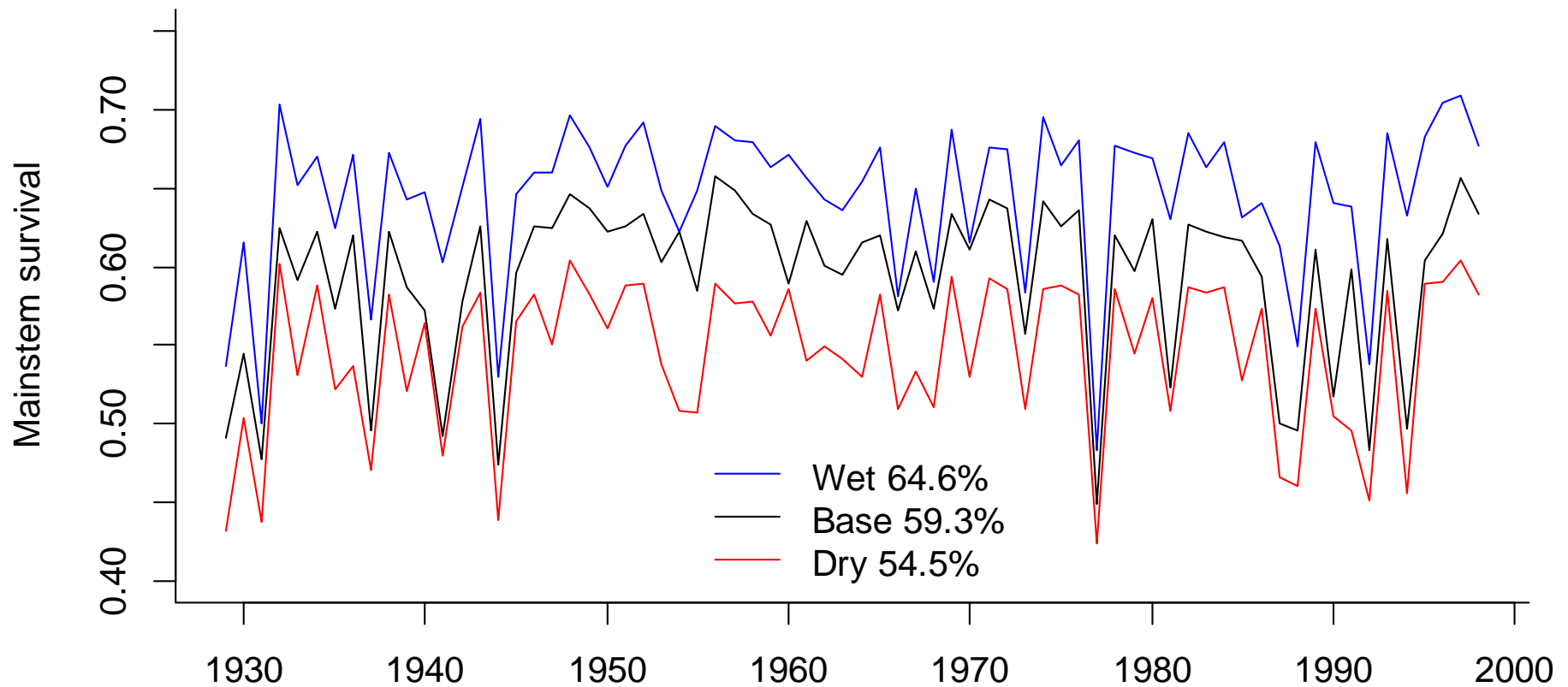
2040s projections



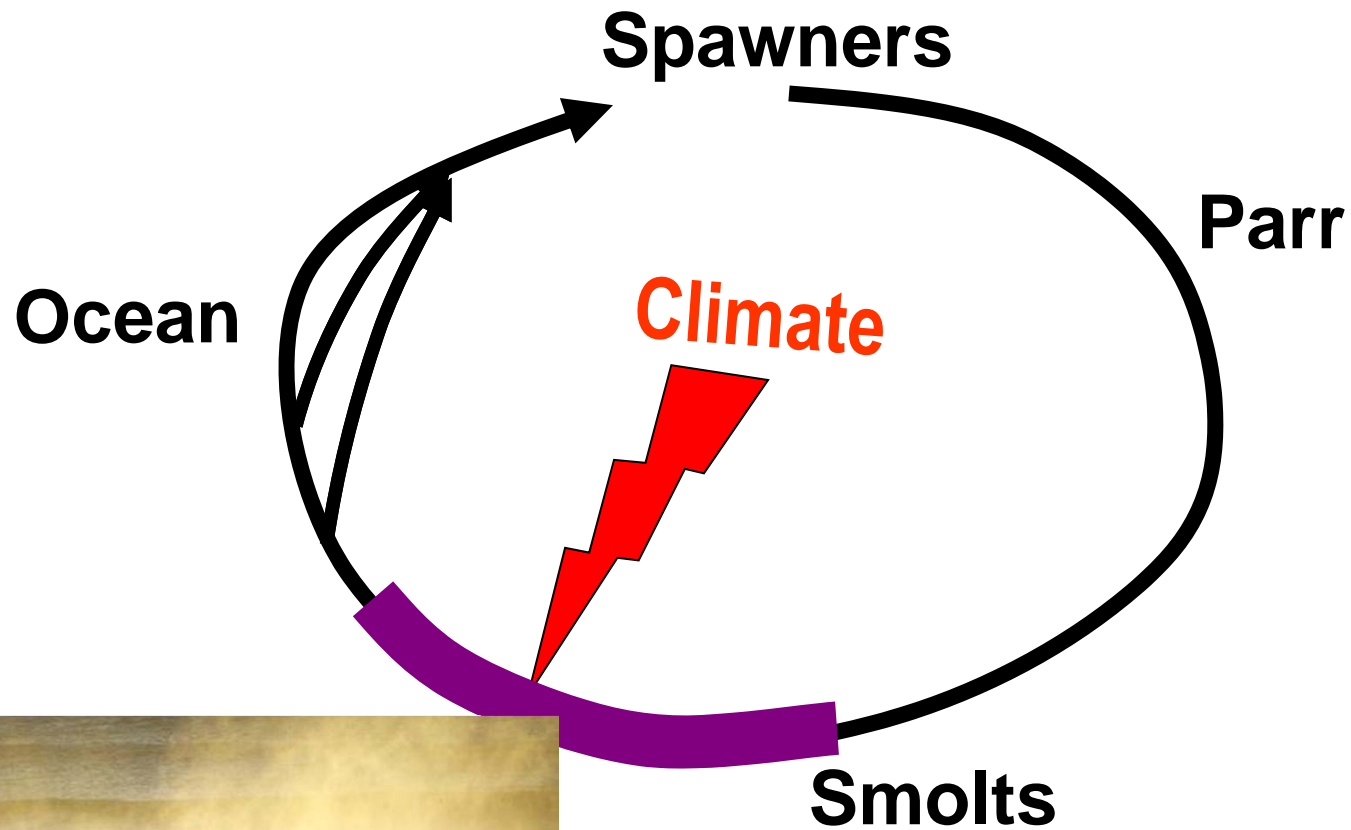
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Smolt survival through the hydrosystem

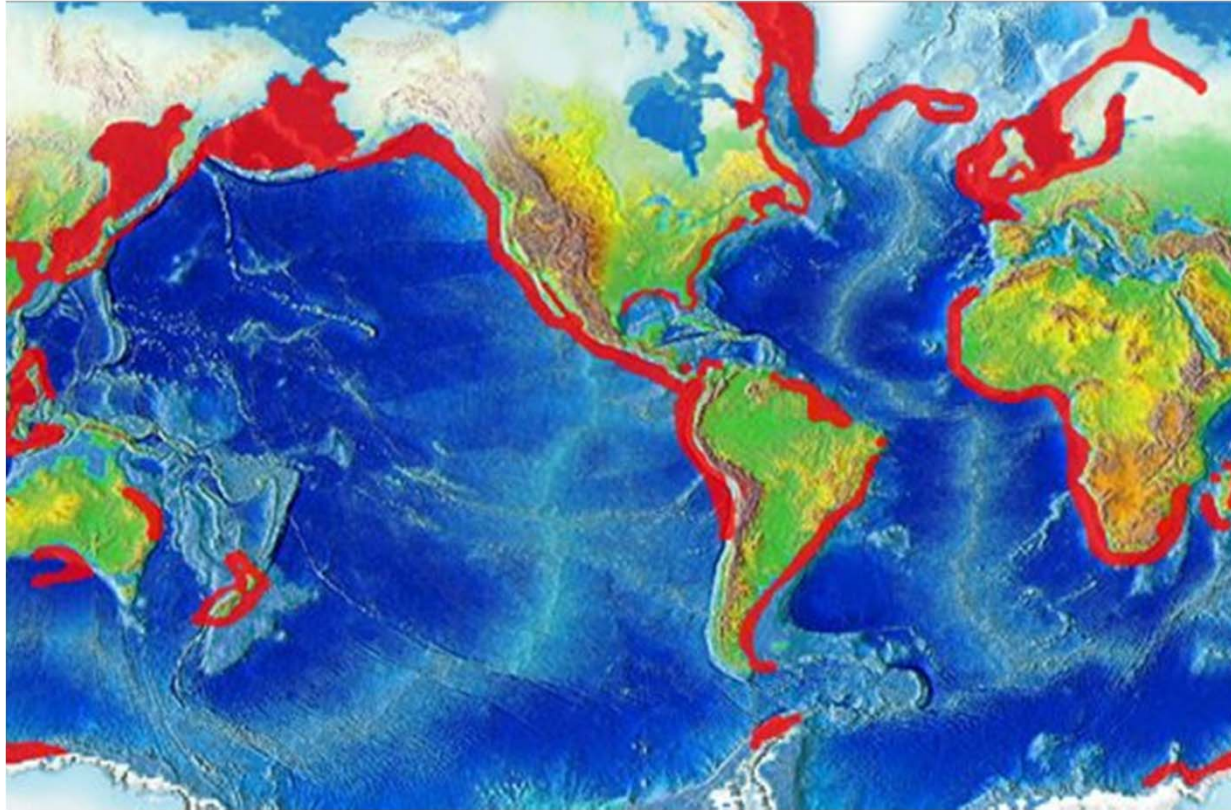
Snake River Chinook



Life-cycle model



Major uncertainties



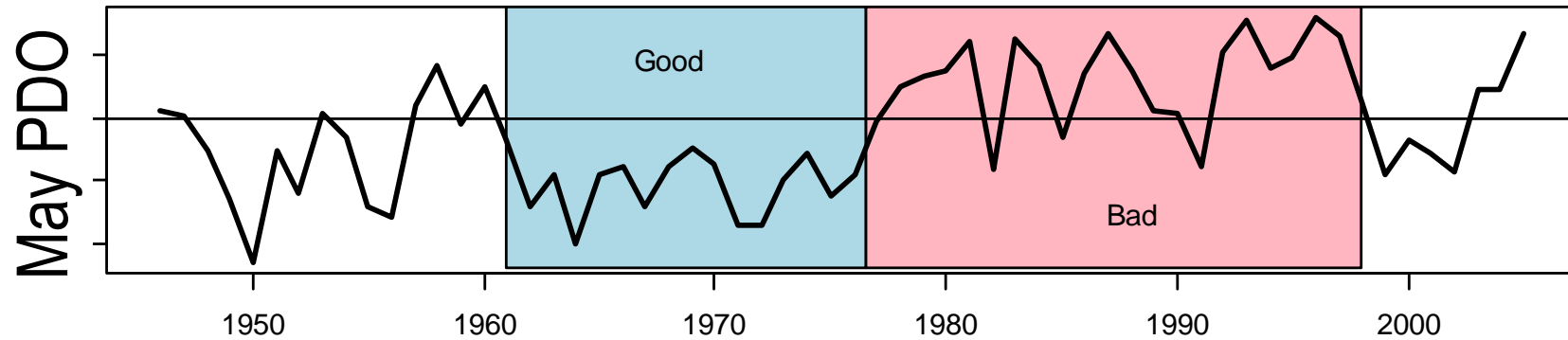
Upwelling zones drive most productive ocean habitats

Intensity \uparrow or \downarrow ?

Importance of timing shifts?

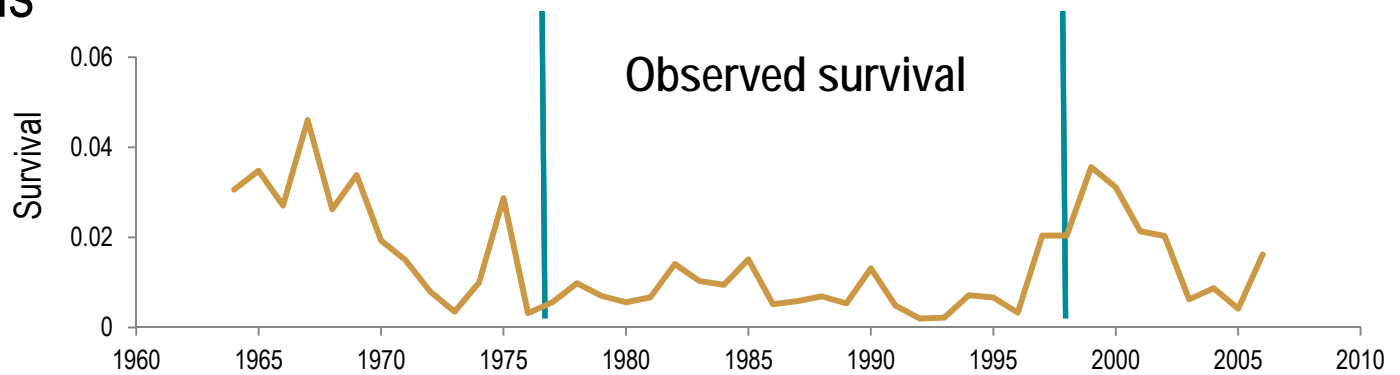
General ocean changes and impacts on salmon?

Ocean regimes



% of time series
in "bad" conditions

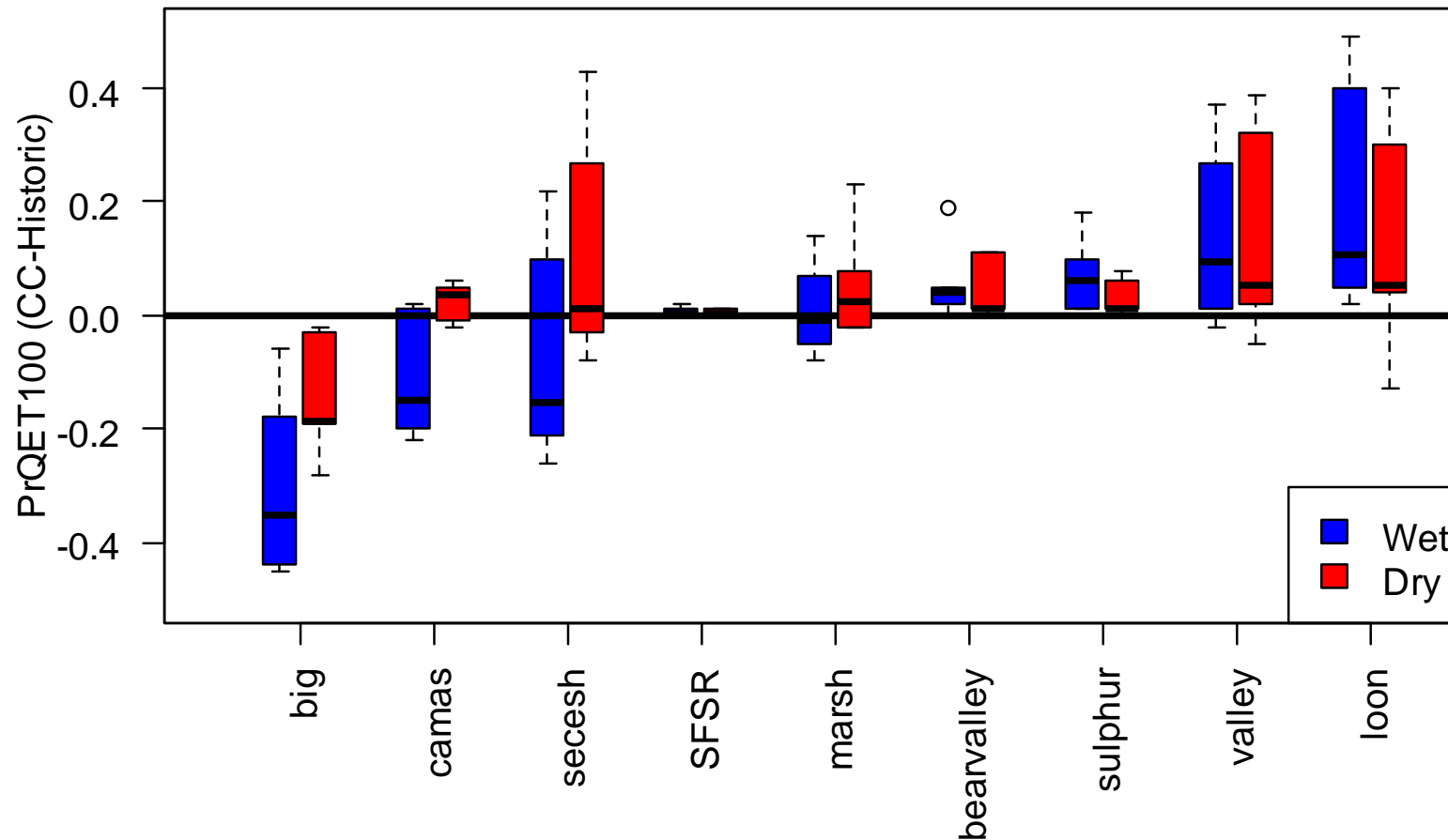
20%
40%
60%
80%



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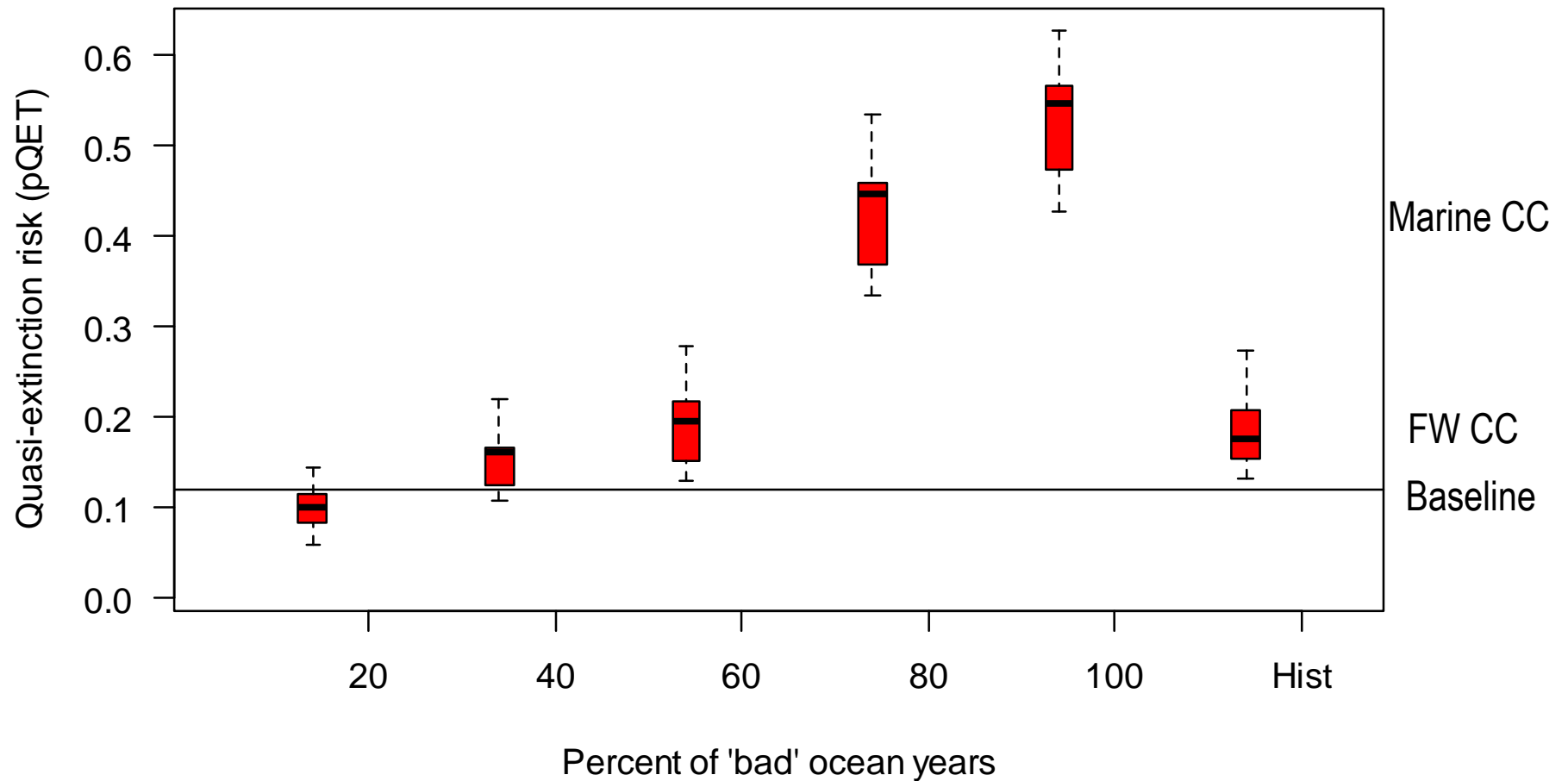
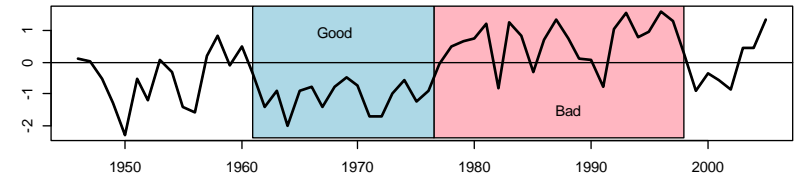
Extinction risk with 2040s climate

Change in population-specific extinction risk
from historical baseline across a wide range of ocean scenarios

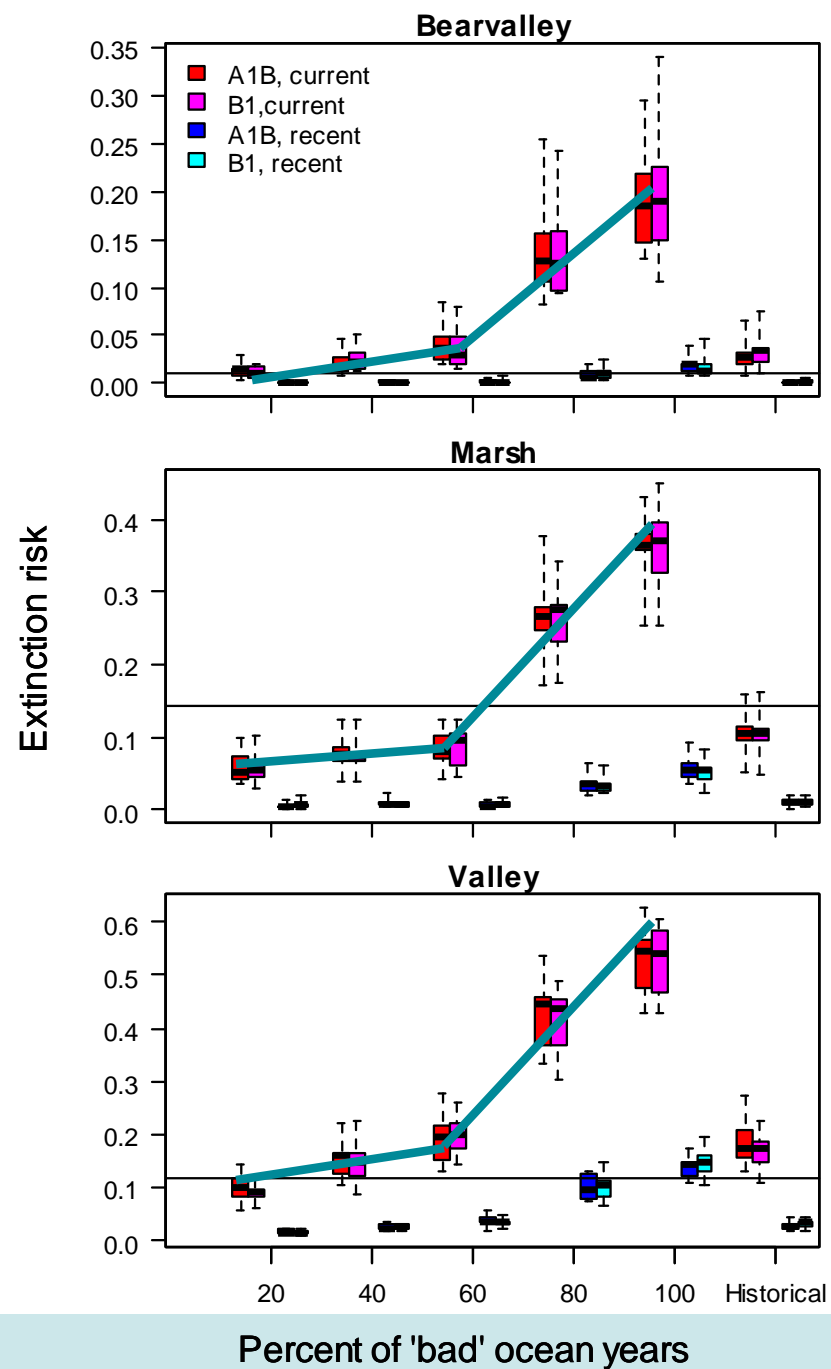


Results: Extinction risk

Valley



Is there a tipping point for ocean conditions?



Threatened species recovery:

At the ESU / Columbia Basin scale,
mainstem Columbia River and
ocean conditions are crucial

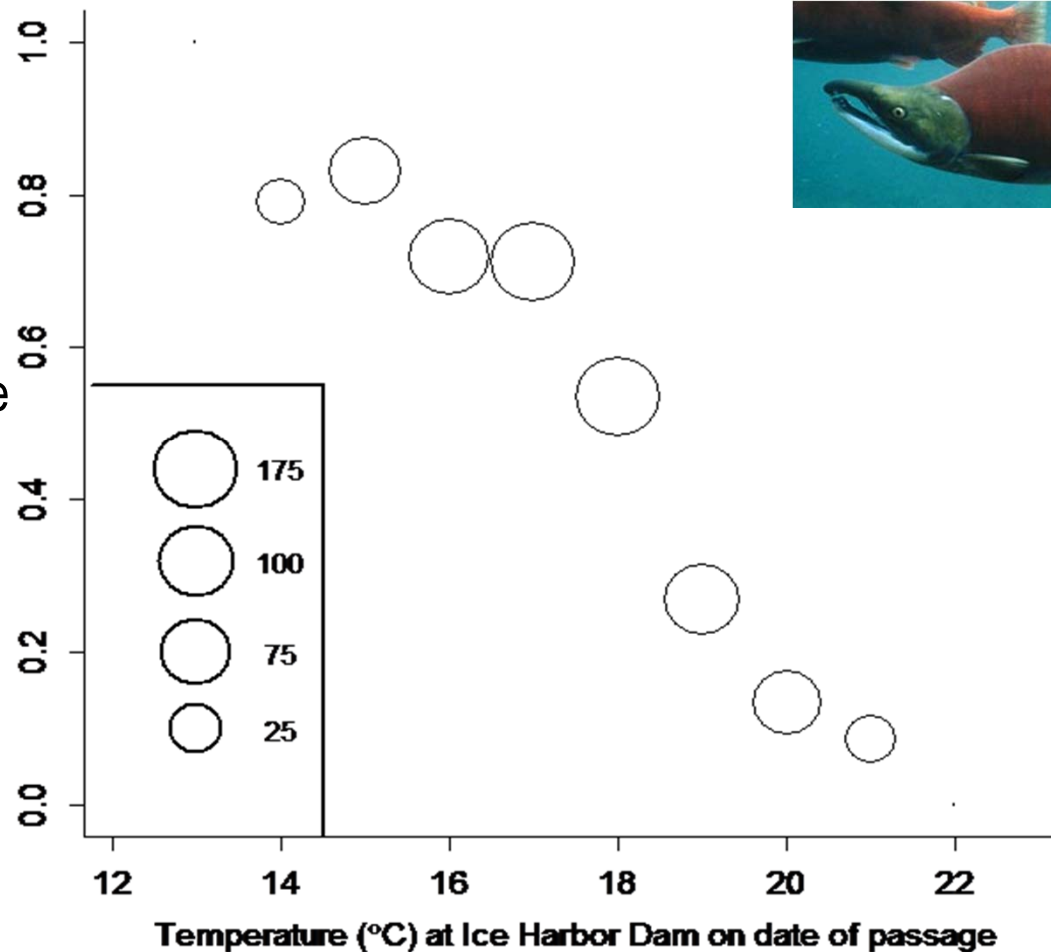


Threatened species recovery:

For local decisions,
e.g. specific restoration actions,
individual population-limiting factors and
individual GCMs are most important

Upstream survival ~ temperature

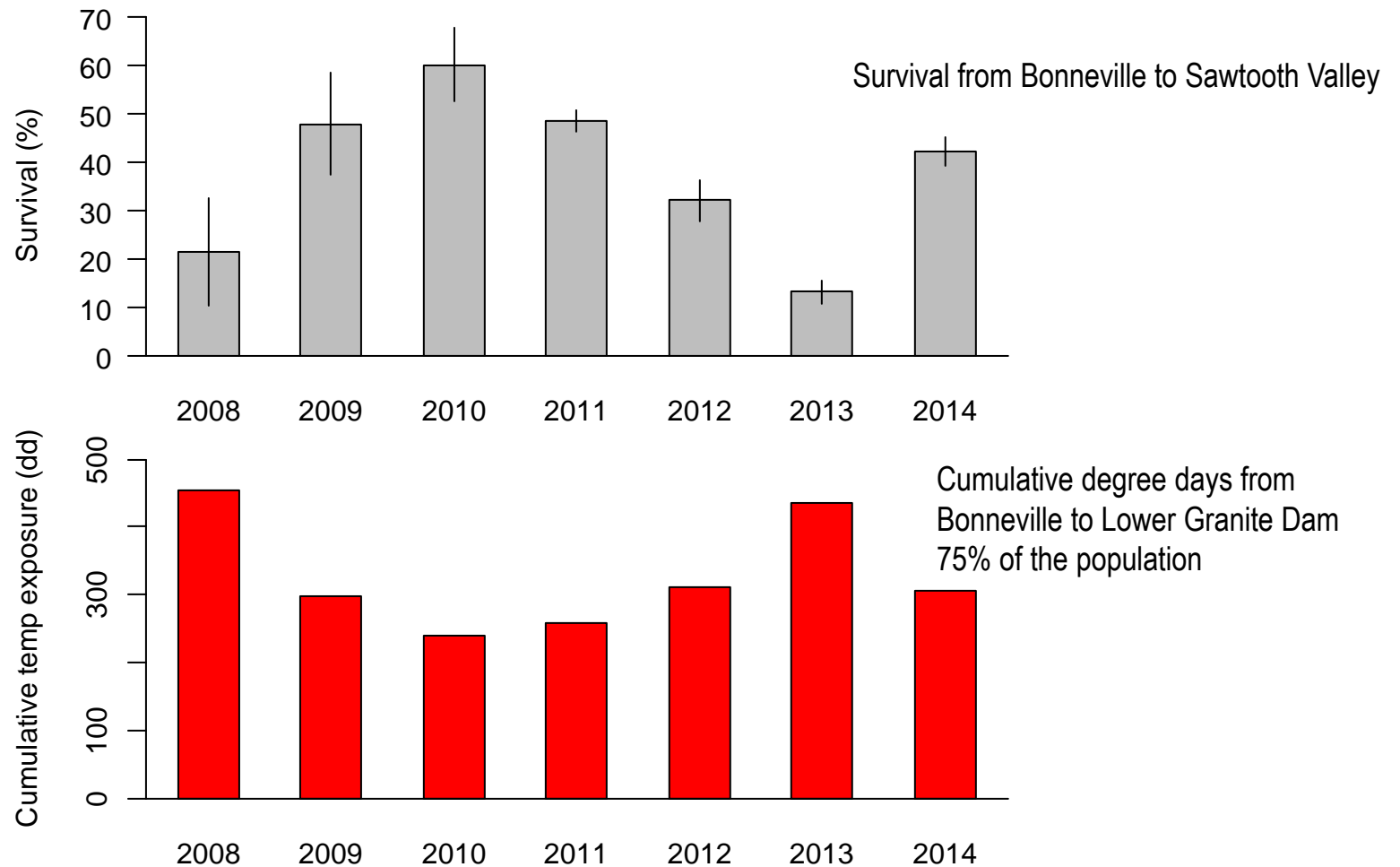
Endangered Redfish Lake sockeye salmon survival from Lower Granite Dam to spawning areas



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Crozier, L. G., B. J. Burke, B. Sanford, G. Axel, and B. L. Sanderson 2014. [Adult Snake River sockeye salmon passage and survival within and upstream of the Federal Columbia River Power System](#). Research report to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Upstream survival highly variable



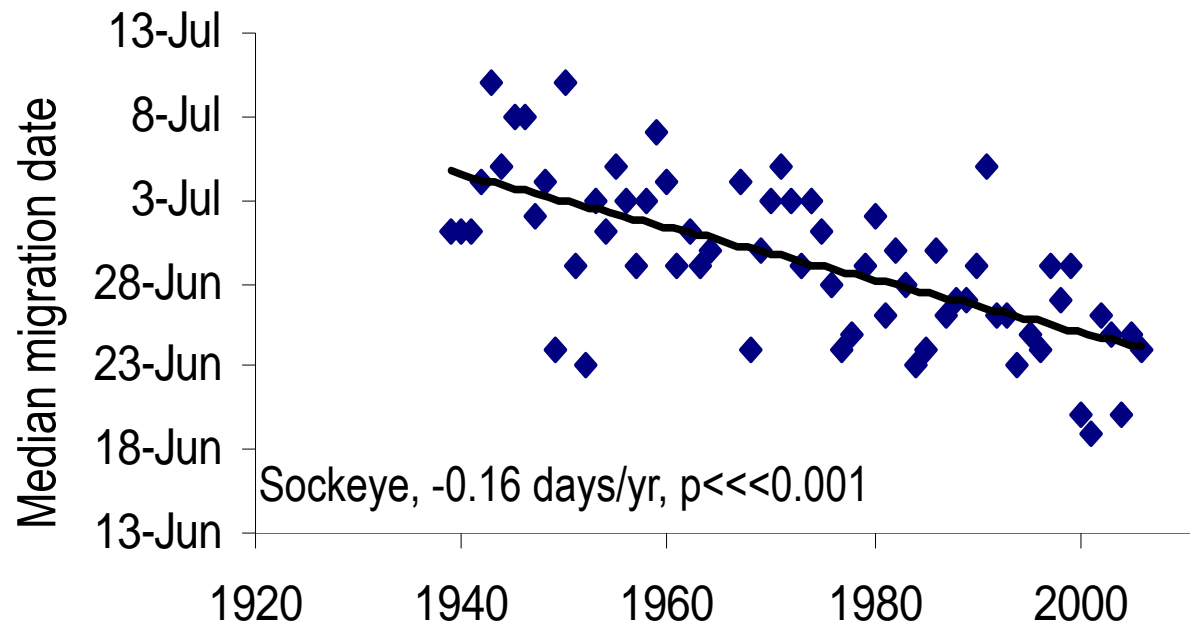
Upstream survival ~ temperature



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Crozier, L. G., B. J. Burke, B. Sanford, G. Axel, and B. L. Sanderson 2014. [Adult Snake River sockeye salmon passage and survival within and upstream of the Federal Columbia River Power System](#). Research report to the U.S. Army Corps of Engineers, Walla Walla, Washington.

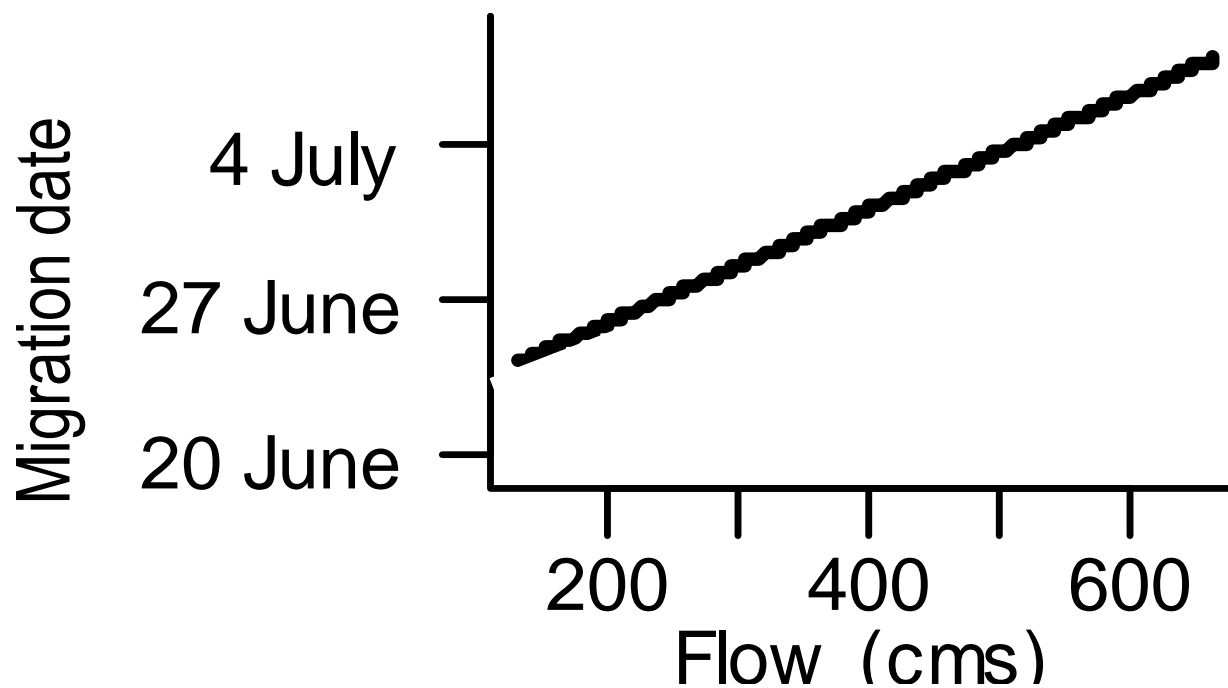
Columbia River sockeye are migrating earlier



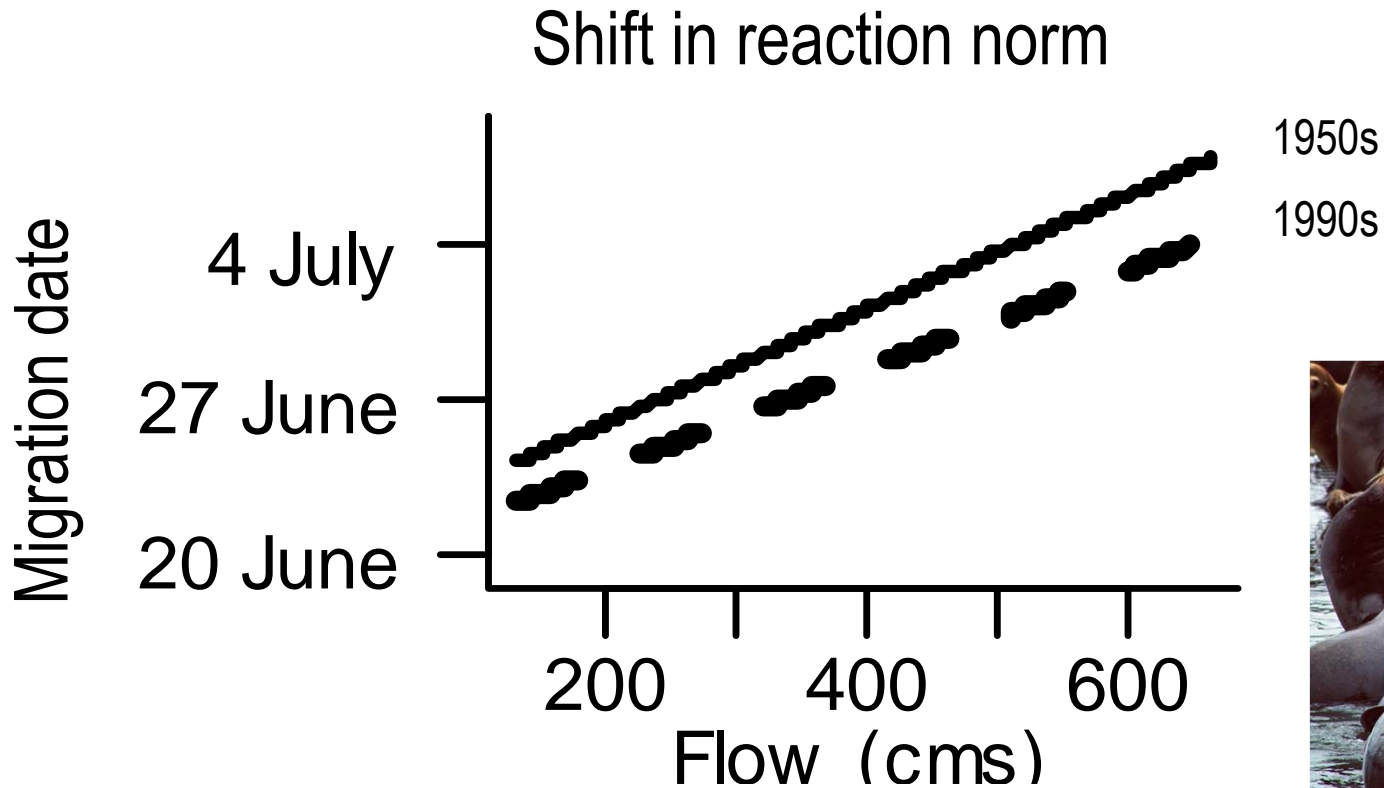
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Fish response: Evolutionary and plastic changes in timing

Reaction norm

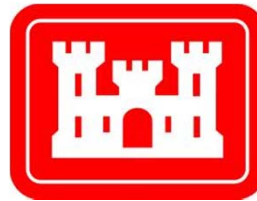


Fish response: Evolutionary and plastic changes in timing



Conclusions

- Climate change will greatly affect salmon even in the most pristine, high elevation habitat, with different effects on different populations
- Effects accumulate over life cycle
- Lowered survival might drive evolutionary or plastic responses; constraints are not well understood, and might limit future evolution
- Uncertainty in climate future more important in ocean than freshwater for most populations
- Management options:
 - Reduce other threats and impacts
 - Build resilience (abundance, habitat networks, diversity and refugia)
 - Triggers for additional actions



Questions?

THANK YOU

- Rich Zabel
- Stephen Achord
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- Robin Waples
- Tom Reed (UW/NWFSC)
- John Williams
- Jeff Hard
- Others at NWFSC...



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